Measurement of Depositing and Bombarding Species Involved in the Plasma Production of Amorphous Silicon and Silicon/Germanium Solar Cells

Quarterly Technical Report
March 1, 2003 – May 31, 2003

DOE Interagency Agreement De-AC36-02G010244

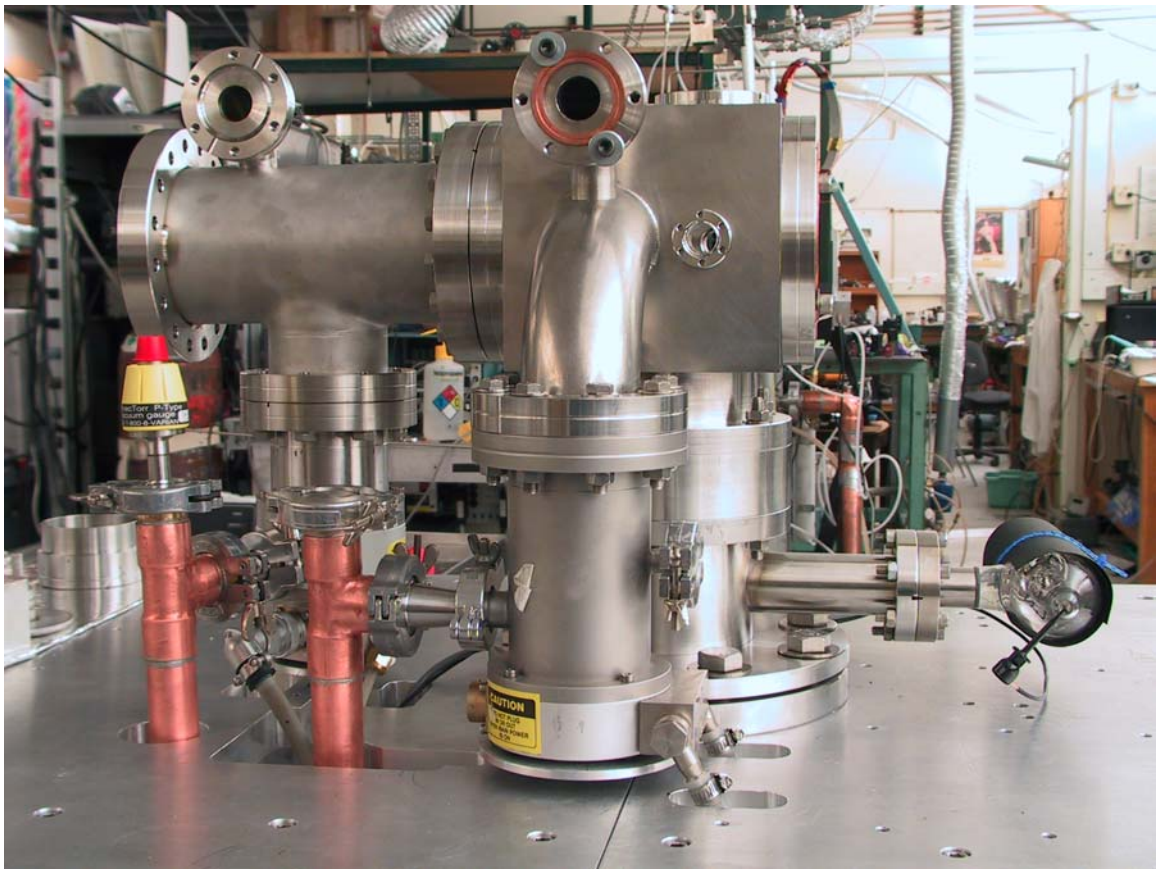
Principal investigator: Alan Gallagher
Contributors: Karoly Rozsa, Peter Horvath, Damir Kujundcik

DOE Program Officer: Ms. Lizana Pierce
NREL Technical monitor: Dr. Bolko Von Roedern

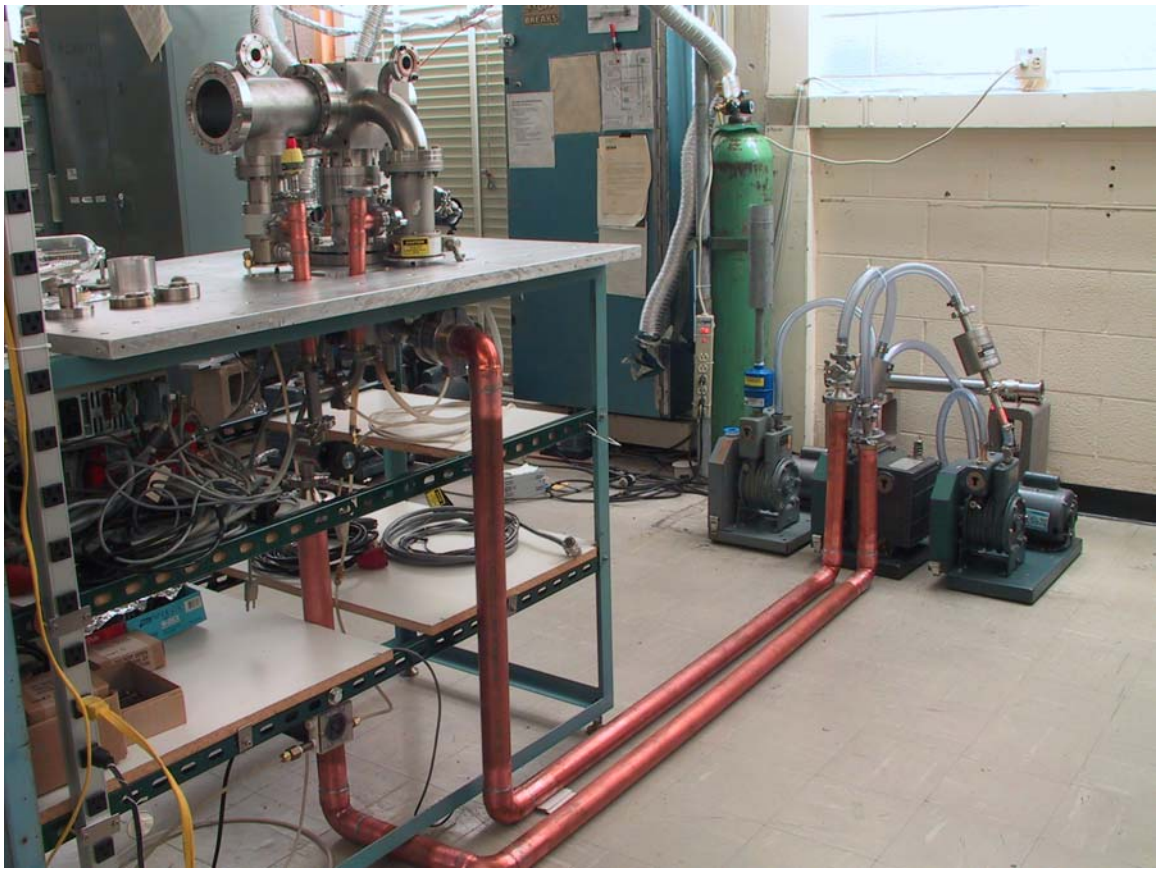
The technical approach to this project, and the apparatus design to achieve it, was described in previous quarterly reports. Briefly, we plan to utilize mass spectrometry to measure radical and ion species that arrive at the substrate of a plasma-enhanced-chemical-vapor-deposition (PECVD) reactor. The reactor will mimic those used to produce hydrogenated amorphous (a-Si:H) and microcrystalline (μc-Si) silicon and silicon/germanium (a-Si:Ge:H) solar cells. Radio frequency (RF) and high frequency (HF) discharges will normally be studied. The reactor will utilize similar electrode gap (2-3 cm), substrate temperature (20-250 °C), gas pressures (0.1-5 Torr), gas mixtures and discharge power density to that used in an industrial reactor.

The core of the apparatus has been constructed, and assembly of the pumping connections and silane pyrolysis chamber is underway. Three turbomolecular pumps and three rough pumps are set up to evacuate four regions of the vacuum chamber. A quadrupole mass spectromerter (QMS) is assembled, for detecting radicals at the discharge substrate surface. The ionizer and ion collection portions of the QMS have been modified for use in threshold ionization mass spectrometry (TIMS). The discharge and TIMS regions are connected by two small orifices and three stages of differential pumping. This arrangement was shown diagrammatically and explained in the previous quarterly reports.

The gas handling system has now been largely constructed and assembled. This includes a ~ 950 °C gas pyrolizer, placed between the rough pumps that evacuate the chambers and another rough pump that prevents air from back streaming into the pyrolizer. This pyrolizes silane (and germane) into surface-bonded Si (and Ge) and H_2 gas that can be safely vented. Similarly, ultra-high vacuum, stainless steel valves control the inlet and outlet gas flows. Photograph 1 shows the core of the apparatus, including the turbo pumps. Fig.2 shows the overall apparatus, including the rough pumps and gas cabinet that contains the silane, germane and hydrogen tanks.



Photograph 1. The assemble vacuum components of the apparatus. Two 50liter/s turbo pumps are visible; the third, 300 liter/s turbo pump is below the table, in the center of the photo. Copper pipes attach to rough pumps ~ 12 feet away.



Photograph 2. Photograph of the full apparatus, including lines to two rough pumps that evacuate the turbo pumps, and a third rough pump that evacuates the pyrolizer. The blue, steel cabinet contains the gas tanks. The 3" diameter discharge chamber and pumping system are designed for up to 10 sccm of silane flow, and up to 20 sccm of hydrogen flow.

Studies of the TIMS apparatus are simultaneously being carried out in a separate vacuum chamber. A principle issue is the ionizer electron energy resolution, which provides discrimination against background ions from dissociative ionization of SiH_4, GeH_4 and H_2. A second issue is pyrolysis of silane (and germane) on the hot cathode, resulting in release of H, SiH_n (and GeH_n) radicals into the ionization region, and thus spurious radical signals. A third issue is the ion collection efficiency and volume. All of these are under study, and in general we are obtaining satisfactory results. These suggest that it should be possible to reliably measure the discharge-produced radicals at conditions that mimic high-quality device production. Prior work, including that of our laboratory ~15 years ago, did not achieve or study signals under conditions that are appropriate for current device production.